Mesoscale Analysis and Forecasting

1e. Given weather products and WS-601, forecast mesoscale weather element IAW an evaluation checklist.

Pressure computations

- Forecasting/calculating sea-level pressure (SLP)
  - Isobars on the surface analysis
  - Numerical weather prediction messages IR
    - Obtain the latest NGM and Eta model output guidance (FOUM66 KWNO and FOUS66 KWNO)
    - Locate the SLP under the "PS" column.
    - The leading 9 or 10 are not encoded

Pressure computations

- Note the 00-hour SLP for each model and compare the 00-hour SLP with the observation for that time
  - Example: KMOB 1200 UTC observation SLP was 1022 mb. NGM 00-hour SLP was 22 and Eta was 21. Use the NGM
- Find the forecast SLP for the time of interest
  - Example: NGM 24-hour forecast is 1023 mb

Pressure computations

- Forecasting the altimeter setting
  - The principles of pressure and altimeter settings was covered in Block I
  - Procedures
    - Obtain current SLP & ALSTG
    - Forecast SLP
    - Determine SLP difference
    - Multiply difference by .03 (1 mb = .03 inches)

Pressure computations

- Add/subtract value obtained to current ALSTG
- Add/subtract diurnal change

Pressure computations

- "D" Value
  - Standard versus observed height (explain using Skew-T)
  - Forecasting “D” Value
    - Obtain actual height of desired level
    - Obtain standard height of desired level
    - Equation: D value = (Actual Height-Standard Height) x 3.3

IR

Pressure computations

- Pressure Altitude
  - Altitude which corresponds to a given pressure
  - Forecasting PA
    - Obtain field elevation and altimeter
    - Equation: PA = FE + [(29.92 - ALSTG) x 1000] IR

Pressure computations

- Density Altitude
  - Altitude in the standard atmosphere of a given density
  - Procedures
    - Computed from pressure and virtual temperature
    - Equation: DA = PA+[120(Actual T_v-Standard T_v)]
    - Standard temperature (If no tables are available)
    - FE x 2 divided by 1000 = x
    - Subtract 15 (sea level standard) from x
    - Change sign

Pressure computations

- Diurnal changes are due to radiational cycle, will vary due to latitude, season, etc.
  - Daily maximums 1000/2200 hours (yearly average)
  - Daily minimums 0400/1600 hours (yearly average)
  - Must be considered whenever you forecast pressure

Winds

- Considerations
  - Pressure gradient
  - Temperature distribution
  - Atmospheric stability

Winds

- Direction
  - Determined by the orientation of the surface isobars (Buy's Ballots Law)
  - Subtract 40° from gradient level direction with speeds 15 knots
    - Don't use with
      - speeds < 15 knots
      - Thunderstorms
      - Frontal passages

Winds

- Friction causes winds to slow and back
  - As much as 15˚-30˚
  - Directly proportionate to speed
- The following factors determine the amount of friction
  - Decreasing stability causes greater friction both horizontally and vertically
  - The rougher the terrain, the greater the effect
- Above the boundary layer, friction is negligible

Winds

- Speed
  - Isobaric spacing represents pressure gradient
  - Speed is approximately 65-85% of low-level geostrophic wind (second standard level)
  - Horizontal and vertical temperature distribution
  - Daytime effects - at maximum heating, maximum vertical mixing occurs, increasing wind speeds

Winds

- Nighttime effects - at maximum cooling, vertical mixing decreases, resulting in lighter winds
- Consider local effects such as channeling, terrain influences, local winds must be considered

Winds

- Local (tertiary) circulations
  - It requires a weak pressure gradients with strong local thermal contrasts (especially in the vertical)
  - Types of local circulations IR
    - Drainage wind occurs at night due to strong cooling
      - High terrain cools and drains into lower areas
      - Shallow sloping terrain/small hills may produce 5 knots
    - Mountain breeze is a stronger case of drainage wind

Winds

- Fall/glacier wind is caused by differential heating associated with snow/ice covered mountains or a glacier
  - Temperature 25-50ºF colder than surroundings
  - Denser air descends lowering surface temps 20˚
  - Not nocturnally dependent
  - Favored geographic regions
    - » Antarctic
    - » Greenland
    - » Alaska Panhandle coasts

Winds

- Valley breeze is opposite of mountain breeze
- Sea breeze occurs during daytime
- Land breeze is the opposite of sea breeze

Winds

- Surface Wind Speed/Direction Forecasting Techniques
  - No inversion present
    - Measure 6˚ latitude upstream, to obtain difference in sea level pressure
    - Convert difference directly to knots
    - Determine direction by orientation of isobars

Winds

- Inversion present
  - Measure 6° latitude upstream; obtain difference in SLP
  - Prior to inversion breaking, mean speed is equal to 40-70% of difference in SLP with no gusts
  - After inversion breaks
  - Mean speed - 100% of differences in SLP
  - Mean gust - 80% of strongest wind 5,000 ft and below
  - Peak gust - 100% of strongest wind 5,000 ft and below
  - Direction is determined orientation of isobars

Winds

- Inversion present, highest winds below inversion
  - Mean speed - measure 6˚ latitude upstream as above
  - Mean gust - 80% of strongest winds below inversion
  - Peak gust - 100% of strongest winds below inversion

Temperature

- Factors that induce temperature change must be considered IR
  - Insolation/radiation
    - Latitude determines the amount of solar energy received at a location
    - Diurnal effects produce a daily cycle of warming and cooling
    - Seasonal effects produce temperature variations on a seasonal basis

Temperature

- Advection
  - Most significant when associated with frontal movements
  - The temperature gradient of a front must be analyzed and forecast with precision

Temperature

- Cloud cover
  - During the day, cloud cover will decrease available insolation
  - During the night, clouds re-radiate terrestrial heat, keeping temperatures higher than on a clear night

Temperature

- Mixing and lapse rates
  - Vertical transport of heat hinges on wind speed
  - Strong wind will permit less low-level heating than weaker wind since the heat energy gained or lost is distributed through a deeper layer
  - Stable lapse rates (low level) usually produce higher surface temperatures than unstable rates due to "capping" of available heat

Temperature

- Condensation occurs during fog formation with the release of latent heat
- Evaporation occurs when cool rain falls into warmer air

Temperature

- Human Influences
  - Larger cities produce a complex effect on their surrounding atmosphere
  - Sources
    - Aerosols
    - Gases
    - Heat
    - Water vapor
  - Cities modify the radiative properties of the earth's surface and terrain roughness

Temperature

- Urban areas produce higher temperatures than surrounding surfaces ("Heat Island effect)
- Industrial emissions increase hygroscopic nuclei and water vapor, thus increasing the probability of "Greenhouse Effect"

Temperature

- Maximum temperature techniques
  - Climatology - use the diurnal temperature curve
    - Adjust forecast maximum
    - Progged synoptic pattern
    - Forecast sky cover
    - Advective effects
    - Climatological records establish boundaries/ranges

Temperature

- Advection of upstream temperatures
  - Best with frontal passage
  - Technique
  - Look for upstream station and obtain maximum temperature
  - Modify at dry adiabatic lapse rate (5.3˚F/1,000 ft of elevation difference)
  - Adjust for cloud cover forecast

Temperature

- Skew-T method
  - Use morning sounding
  - For forecast dry conditions (CLR-SCT)
  - Find 850-mb temperature and extend a line dry adiabatically to surface and read isotherm
  - For forecasted moist conditions (BKN-OVC, precipitation)
  - Find 850-mb temperature and extend a line moist adiabatically to surface
  - Read isotherm

Temperature

- Minimum temperature
  - Climatology - use the diurnal temperature curve
    - Adjust forecast minimum according to
    - Progged synoptic pattern
    - Forecast sky cover
    - Advective effects
    - Climatological records establish boundaries/ranges

Temperature

- Skew-T method
  - Use the evening sounding
  - Do not use when forecasting BKN-OVC and/or precipitation
  - Find 850-mb dew point and extend a line moist adiabatically to the surface and read isotherm
- Dew point method - use surface dew point at time of maximum heating IR

Temperature

- Specialized temperature forecasts
  - Various customers may have a need for a specialized temperature forecast
  - You must be prepared to provide such forecasts as
    - Runway versus free air temperature (take into consideration that concrete heats and cools faster than the ground)
    - Tailored forecast products (wind chill, heat stress, survival times, degree-days, etc.)
  - Use of climatology and local studies

Temperature

- Cold Wave
  - It is a rapid fall in temperature within 24 hours to a prescribed minimum depending on region and time of year
  - General synoptic features
    - Long-wave trough east of your station
    - Long-wave ridge to west of station
    - Most cold waves persist 48-72 hours

Temperature

- Temperatures will rise due to air mass modifications
- A quasi-stationary long-wave ridge could extend duration

Temperature

- Heat wave
  - It is a period of abnormally hot, humid weather lasting for several days or weeks
  - General synoptic features
    - Ridge east of your station
    - Long-wave trough west
    - Once pattern has been established, it will remain until long-wave ridge moves or breaks down

Clouds

- Cloud forecasting tools IR
  - Climatology is a time-proven method and is derived from decades of data.
  - Numerical weather prediction
    - Model Output Statistics (MOS) guidance derives forecasting relationships by correlating past model output with station climatology

Clouds

- The “R” numbers (R1, R2 and R3 values) in the NGM and Eta numerical messages specify forecast relative humidity values for layers of the atmosphere above a data point
  - R1 is the relative humidity of the surface to the 1,000 foot layer centered near 500 feet AGL
  - R2 is the relative humidity of the 1,000-17,000 foot layer centered near 9,000 feet AGL.
  - R3 is the relative humidity of the 17,000-39,000 foot layer centered near 28,000 feet AGL.

Clouds

- Cloud forecasting techniques
  - Stratiform cloud types
    - Stratus
      - Generally stable atmosphere
      - Cooling must occur in moist layer
      - Fog and stratus are typical of warm air masses
      - Bases usually less than 2,000 ft (identify bases when RH is 65 to 70% on RAOB

- 1,000-4,000 ft thick
- Tops found where RH falls to less than 65 to 70%
- Synoptic conditions favorable for development
  - » Areas of weak convergence and high moisture content
  - » Warm moist air over a cooler surface with slight upward vertical motion
  - » Areas of slight cyclonic turning IR
  - » Gradual upslope conditions
  - » Warm frontal zone
  - » Advection fog being lifted (turbulent mixing)

Clouds

- Forecasting formation/dissipation
  - » Gulf stratus studies
  - » Thicker layers will inhibit surface heating, thus maintaining temp/dew point relationship
  - » Local studies of terrain anomalies will help
  - » Forecast heating/cooling effects

Clouds

» Skew-T method

a. From temperature at base of stratus layer, follow dry adiabat to surface

b. This is the temperature required to begin dissipation

c. Follow dry adiabat from temp at top of layer to surface; this is the temperature needed to dissipate entire cloud

» On average 360 feet of cloud will dissipate for every hour of heating

Clouds

- Nimbostratus
  - Relatively stable atmosphere
  - NS usually forms from thickening AS
  - Associated with moderate to heavy continuous precipitation
  - Bases where RH equals or is greater than 65-70% (in low-cloud range)
  - Tops where RH is less than 65-70% (in mid etage)

Clouds

- Synoptic feature - well-developed cyclone with warm/quasi-stationary/occluded front
- Forecasting
  - » Forecast the synoptic feature causing formation
  - » Forecast thickening/lowering based on moisture availability
  - » If sufficient mid-level instability develops, NS may become AC

Clouds

- Stratocumulus
  - Formation
  - May form from lifted ST or spreading CU
  - SC also forms as moisture is lifted through conditionally unstable air
  - Conditionally stable/unstable atmosphere
  - Bases: RH first increases to 65-70% (Approximately 1,500 to 6,500 ft)
  - Tops - falling below RH of 65-70%
  - Thickness - 1,000-4,000 ft

Clouds

- Synoptic feature
  - » Unstable low level with inversion above
  - » Cold air advected over warmer surface
  - » Leeside of large water bodies in winter
  - » SE quadrant of sub-tropical ridge

Clouds

- Can form in stable air, which is nearly saturated
  - » Top of layer cools (terrestrial radiation emitted)
  - » Lower layer warms (terrestrial radiation absorbed)
  - » Moisture distribution becomes more uniform
    1. Lower layer (warming) dries
    2. Upper layer (cooling) moisture increases
  - » Upper layer remains stable (possible inversion)
  - » Cumuliform clouds will form if upward motion pushes through stable layer

Clouds

- Cirriform cloud types
  - Normally found 300-500 nm ahead of surface warm front
  - True cirrus forms at temps near -35˚C, the crystals form then descend to -25 to -35˚C
  - When precipitation is falling, there is a 60% chance that cirrus is present above the precipitation
  - Frequently associated with CB anvils
  - Found around well-developed surface cyclones

Clouds

- Vicinity of Polar-Front Jet (generally on -N side)
- Frequently found in anti-cyclonic curvature above 400 mb
- The probability of cirrus is best with W-SW flow
- The most extensive and thick cirrus is located within a few thousand feet of the polar tropopause
- The average depth of a cirrus layer is 800 feet, but can be as much as 10,000 feet

Clouds

- Cirrus in a forming difluent flow will dissipate
- Types of cirrus
  - 1 Advective cirrus appears to have a relationship to the orientation, wavelength and amplitude of the jet streak
  - Convective cirrus is associated with thunderstorms and frontal systems.

Clouds

- Convective cloud types
  - Unstable atmosphere
  - Rarely overcast
  - Exceptions being
    - Supercell
    - Meso-scale convective complexes
    - Cumulonimbus embedded in nimbostratus in warm front

Clouds

- Bases
  - LCL - when lifted mechanically (frontal or orographic)
  - CCL - when lifted by thermal means (surface heating)
- Tops may exist where RH is less than 70% (forecast tops as taught in Block V)

Clouds

- Cloud dissipation sequence with fronts
  - Low clouds **begin** to dissipate with passage of 850-mb trough and **completely** dissipate with passage of 700-mb trough
  - Mid clouds **begin** to dissipate with passage of 700-mb trough and **completely** dissipate with passage of 500-mb trough
  - High clouds **begin** to dissipate with passage of 500-mb trough and **completely** dissipate with passage of 500-mb thermal trough

Clouds

- Seasonal air mass clouds are caused by surface heating, orographic lift, or onshore flow
  - Summer
    - cP (source region) - scattered Cu and SC
    - mP (Pacific coast) - stratiform low and mid clouds
    - mP (east coast) - CU
    - mT (Pacific coast) - SC/ST/FG
    - mT (east/gulf coast) - ST/FG/SC early in morning becoming CU/TCU/CB in afternoon
    - cT - SCT CU

Clouds

- Winter
  - cP (source region) - few if any clouds
  - cP (SE of large water bodies) - SC/CU
  - mP (east coast) - ST/SC/FG
  - mP (Pacific coast) - CU
  - mT - ST/SC

Clouds

- Precipitation effects on cloud bases
  - Bases lower (at unsteady rates)
    - The addition of moisture
    - Evaporative cooling of the atmosphere
  - Continuous rain rules
    - If rain is of sufficient duration, ceiling will often descend to or form below 2,000 ft and often to less than 800 feet
    - Occurs in staggered stages
    - Observe trends over a given time
    - When coupled with synoptic scale analysis is a useful tool

Clouds

- Showery precipitation must be extremely heavy to significantly lower cloud bases
  - Will rapidly drop
  - Often below 2,000 feet

Clouds

- Vorticity is related to the vertical motion in the atmosphere which is related to cloud formation and dissipation

Clouds

- Review
  - A major problem in cloud forecasting is local variations
  - Clouds often form under cyclonically curved contours aloft, when no surface feature exists
  - In a cold air mass, clouds form when the air is following a cyclonically curved path
  - Air that is flowing south anticyclonically or in a straight line will promote clear skies

Precipitation

- Precipitation forecasts depend upon 4 factors
  - Temperature forecast
  - Atmospheric stability (vertical motion)
  - Moisture availability
  - Cloud type forecast

Precipitation

- Precipitation Types
  - Continuous Precipitation (Stratiform)
    - Warm, moist air being orographically lifted
    - Ahead of warm of stationary front (overrunning)
    - In an area of upper-level troughing associated with divergence
    - Right rear/left front quadrant(s) of a jet max

Precipitation

- Showery Precipitation (cumuliform)
  - Need vertical development
    - At least 8,000 feet to 10,000 feet thick
    - Tops -12ºC to -20ºC or colder
  - Cloud bases **may** be above freezing

Precipitation

- Rain may occur with either warm or cold rain process
  - Warm rain process is where the entire cloud at temps above freezing
  - Cold rain process is where the cloud and precipitation occur at temperatures below freezing
  - Most precipitation in mid-latitudes is cold rain
  - Freezing level greater than 1,200 feet AGL

Precipitation

- Factors that increase the chance of rain
  - Cloud top temperatures of $\leq$-12˚
  - $\geq$ 8,000’ cloud depth

Precipitation

- Drizzle is always warm rain process
  - Cloud layer 2,000’ thick
  - Layer must persist for several hours (allow droplets time to grow)
  - Must have sufficient upward vertical motion to maintain clouds
  - Once drizzle begins, a moisture source must be available to sustain cloud formation

Precipitation

- Low-level streamlines (assuming moisture is available) to identify confluence
- A study showed that nearly 87% of drizzle cases occurred with cloud top temperatures of >-5°C

Precipitation

- Precipitation forecasting using Skew-T
  - Moisture content
    - RH indicates chance of precipitation
    - Mixing ratio is used to estimate precipitation amount (absolute humidity)
    - $T\text{-}T_d$ of 2° or less signifies precipitation

Precipitation

- Vertical motion determines increase/decrease of cloud depth
  - Neutral/downward motion indicates dissipation
  - Upward/increased upward motion can indicate change of precipitation type (drizzle to rain or continuos to convective precipitation)

Precipitation

- Precipitation will change freezing levels
  - Evaporative cooling
    - The freezing (or melting) level may lower 500-1,000 ft in first 1½ hours after precipitation begins (evaporative effects continue until atmosphere is saturated)
    - When the air is saturated evaporation ceases and freezing level will return to original level within 3 hours (exclusive of advection)

Precipitation

- Freezing levels are raised through release of latent heat
- Temperature/moisture advection will cause a change in the freezing level

Precipitation

- Vorticity
  - With sufficient moisture available and decreasing stability, forecast precipitation to begin with the onset of strong PVA

Precipitation

- Progging precipitation using vorticity
  - The beginning and ending of precipitation is often associated with a particular vorticity isopleth
  - Prog new precipitation areas based on this same value.
  - Three cases where this technique will not work
    - Orographic precipitation.
    - Precipitation from stratus or precipitation produced strictly by low-level effects
    - Precipitation from systems too shallow to be evident at 500 mb

Precipitation

- Precipitation Forecasting Using Satellite Imagery
  - General
    - Infra-red
      - Cooling cloud tops or an expansion in area of cold tops indicates an increase in UVM
      - Warming of tops indicates the converse

Precipitation

- Visible
  - The more textured the cloud tops on visual imagery, the stronger the convection occurring within the cloud
  - Areas of increased or increasing UVM will appear "lumpy" on visual channels

Precipitation

- Synoptic scale systems
  - Deformation Zone Cloud Systems
    - Moderate to heavy precipitation in southern quarter of cloud area
    - Sharp decrease in precipitation at southern edge of cloud shield
    - Gradual decrease in precipitation from southern sections of cloud shield
    - Usually stratiform clouds, steady or continuous types of precipitation
    - Movement of precipitation area is slower than the precipitation area associated with parent system

Precipitation

- Baroclinic zone cloud systems
  - Usually topped with cold cirriform clouds
  - Cold tops appear more scattered on IR channels than with deformation zone systems
  - Northern reaches of cloud band are typically composed of cirriform and high mid-clouds and is largely precipitation free
  - Southern portions of cloud band are composed of stratiform clouds and light steady precipitation
  - Coldest and highly textured cloud tops are associated with convection and moderate to heavy precipitation and showers

Precipitation

- Vorticity comma cloud systems
  - Cloudiness composing this synoptic pattern often extends to mid levels and may not appear as enhanced on standard IR channels
  - Highly textured appearance is commonly found through the cloud system and is evidence of showery precipitation associated with the upper-level vortex
  - Strong thunderstorms may be found in the comma as indicated by the scattered cold tops on IR and pronounced shadows as seen on visual channels

Precipitation

- Baroclinic leaf cloud systems
  - Little or no precipitation forms in northeast portion of cloud pattern
  - Light showery precipitation falls from southern boundary of cloud band
  - Moderate to heavy precipitation falls from convective clouds indicated by the scattered cold tops in center of cloud band
  - Overshooting tops may appear on VIS
  - Light continuous precipitation falls from western portions of cloud area

Precipitation

- Model Output Statistics (MOS) guidance is usually a reliable tool for forecasting precipitation since it considers climatology for your station.

Visibility and restrictions

- This is defined as the greatest distance at which selected objects can be seen and identified
- Fog is the most common restictor of visibility
  - For fog formation you need
    - Cooling processes
      - Radiation (nocturnal cooling)
      - Advection of warm air over cooler surface
      - Adiabatic cooling (orographic, frontal, and turbulent lifting)
      - Evaporational cooling

Visibility and restrictions

- Moisture
  - Evaporation (i.e., precipitation falling into colder air)
  - Adding condensation nuclei (burning hydrocarbons)
  - Cold air over warm water or saturated surface
  - Residual (fallen precipitation)
- Mixing
  - Weak eddy currents can increase moisture throughout layer of interest
  - Mixing of two nearly saturated air masses (one warm and one cold) along a front

Visibility and restrictions

- Dissipation
  - Heating
    - Insolation (solar heating)
    - Advection over warmer surface
    - Adiabatic (downslope) heating
  - Remove moisture
    - Mixing with drier air
    - Condensation and precipitation (dew, rain etc.)
  - Mixing with drier air aloft

Visibility and restrictions

- Types of fog
  - Fogs formed by cooling
  - Radiation Fog
    - Occurs when moist air-cools to its dew point through nocturnal cooling or when maritime air becomes stagnant over a colder surface
    - Requirements
      - » Weak pressure gradient
      - » Especially low clouds with precipitation
      - » Clear skies at night (or high thin cirrus)

Visibility and restrictions

- » A dew point that is constant or increasing with height in the lower 200-300' AGL
- » Regions dominated by warm barotropic highs
- » Late autumn and winter, long nights-shorter days
- » May combine with advection fog
- » Commons over east coasts of continents late fall and winter

– Radiational fog does not form over snowfields (advection fog may form over snowfields with WAA in low layers)

– Dissipates with surface heating or strong mixing

Visibility and restrictions

- Continental high inversion fog
  - Associated with an inversion based a few hundred to a few thousand feet above the surface
  - Takes several nights of cooling
  - Low levels have access to map air (under inversion)
  - Stratus forms at base of inversion during day and lowers to surface at night
  - Visibility often near zero

Visibility and restrictions

- May last for days or weeks
- Most common in western U.S. valleys in winter (San Joaquin, Utah, Great Basin etc.)
- Dissipates with change of air mass

Visibility and restrictions

- Advection Fog
  - Produced by the transport of warm moist air over colder surfaces
  - Maritime air over land or colder waters
  - Wind less than 3 knots, fog is shallow
  - Wind 3-9 knots, ideal for deep fog
  - Wind greater than 9 knots, too much mixing for fog, stratus formation most likely
  - Most common along coastal regions, extends 150-250 nm inland, depending on terrain and wind field

Visibility and restrictions

- Western side of Bermuda high and mid-Pacific ridge
- Southerly flow on western side of a baroclinic high that has moved over water
- Dissipates with surface heating or strong winds

- Upslope Fog
  - Fog forming due to **gradual** orographic lift, cooling air adiabatically to its dew points
  - Forms as a stratus layer, in staggered stages at higher altitudes
  - Descends to the surface, as air is adiabatically cooled moving upslope (Terrain lifting will cool air at dry lapse rate 5.3 ˚F per 1,000')
  - Exists with stronger winds as adiabatic cooling also increases

Visibility and restrictions

- Dissipates with change of air mass or surface heating
- Favored geographic areas in North America include
  - » The Great Plains of the U.S. and Canada
  - » The Piedmont east of the Appalachians
  - » Eastern slopes of the Rocky Mountains

Visibility and restrictions

- Sea Fog/Stratus
  - Advection fog which forms when warm moist air moves over colder water
  - May also be a cold water mass (not a current) at higher latitudes
  - Dew point is initially higher than sea surface temperature
    - » Temps are lowered as air is modified from below
    - » If dew points are colder than the water, fog is unlikely
  - May lift to stratus when advecting on shore (lifting caused by slight cyclonic turning)

Visibility and restrictions

- Can exist with strong winds when temps are quite cool (30-40˚F)
- Increasing wind speeds may lift fog to stratus without breaking up (if air layer temp near SST)
- Dissipates by modifying air mass (frontal passage or stagnation with time)
- Dissipates when moving over warmer land

Visibility and restrictions

- Ice Fog
  - Occurs in areas of human habitation at high latitudes
  - Water is added by burning hydrocarbons
  - It is possible for an aircraft to produce its own IFR conditions when starting its engines

Visibility and restrictions

- Evaporation fogs
  - Steam Fog
    - Cold air over warmer water, usually 2-3 feet thick
    - Caused by rapid evaporation of moisture into relatively cold air
    - Most common in mid-latitudes in fall or early winter, over lakes and rivers
    - Dissipates as air heats

Visibility and restrictions

- Warm Front (most common frontal fog)
  - Pre-frontal fog
  - Widespread - usually mT overriding cP
  - Northeast CONUS most provides classic scenarios of warm frontal fogs
    - » Caused by warm rain falling into cooler air
    - » Dew-point temperature of warm air mass higher than temperature of cold air mass

Visibility and restrictions

  - » Daytime stratus formation due to evaporation and turbulent mixing
  - » Evaporation
  - » Turbulent mixing (heating)
- – Lowers to surface during the night.
- – Ceilings will be above 300 feet with winds >25 knots

Visibility and restrictions

- Cold Fronts
  - Occurs with both active and inactive **shallow** cold fronts
  - Usually found 150-200 nm behind front
  - Due to (saturated surface) precipitation falling into cooler air

Visibility and restrictions

- Fog Forecasting
  - The forecaster must consider
    - Climatology
    - Air mass qualities
    - Air mass modification through trajectories
    - Surface/low level interface
  - Determining fog height from the skew-T
    - Determine height of average mixing ratio
    - Intersection with temp curve (CCL_{ML}) is the height

Visibility and restrictions

- Graphic Fog formation method (demonstrate technique to students on marker board)
- Objective method (Fog Point)
  - Forecasting radiation fog
  - Value indicates temperature at which fog will form
    - » Find LCL ($_{ML}$)
    - » From dew point at this pressure level, follow saturation mixing ratio line to surface (Temperature at surface is Fog Point)

Visibility and restrictions

- Rules-of-thumb for fog dissipation
  - If advection fog is present, fog usually lifts to stratus first
  - If radiation fog is present, fog usually burns off
  - Modifying or changing the air mass over a region, from stable to unstable will eliminate or reduce fog

Visibility and restrictions

- Objective Skew-T method
  - Find where average mixing ratio intersects temperature curve
  - Follow intersection dry adiabatically to surface, read temperature
  - This is temp needed to dissipate fog

Visibility and restrictions

- Haze
  - What haze is
    - A vast blanket of man-made pollution
    - Types of haze
    - “Wet” air pollution is a veil of tiny droplets (aerosols) of condensed pollutants found in the eastern U.S.
    - “Dry” haze consists of fine dust particles found elsewhere in the world (e.g., the Harmattan haze of west Africa, or the Shamal wind haze of the Persian Gulf)

Visibility and restrictions

- Chemistry of haze
  - Haze aerosols form from the oxidation of SO_2 and may exist in solid or liquid form
  - Airborne sulfates also originate from bursting air bubbles in ocean waves or over arid regions, from wind abrasion of sulfate-bearing soils

Visibility and restrictions

- Man-made SO_2 is produced in great quantities during large-scale combustion of sulfur-bearing fossil fuels in power plants, oil refineries, and steel mills
  - Mid Mississippi Valley
  - Mid Atlantic states
  - Lower Great Lakes
  - Texas and Louisiana coasts

Visibility and restrictions

- Climatology of haze
  - Because large-scale atmospheric transport reaches a minimum during the summer and boundary layer relative humidity tends to be high; sulfate haze is primarily a warm season phenomenon
  - The eastern U.S. is located to the west of the semi-permanent Bermuda anticyclone, which makes it prone to prolong episodes of synoptic-scale haze in summer
  - There is limited vertical mixing east of the Appalachians because of subsidence

Visibility and restrictions

- Summer days are long and large-scale cloudiness is at a minimum enhances the formation of liquid or solid aerosols from SO_2 gas
- Haze forms primarily in cP air mass which has undergone strong modification in the lowest layers and is returning poleward after having overspread the eastern states two or three days before
- A subsidence inversion is present around 850 or 900 mb, which traps moisture and haze aerosols near the surface

Visibility and restrictions

- Some of the worst haze episodes are associated with the blocking of polluted air masses over the Ohio Valley or Midwest when tropical cyclones are present along the East Coast
- Haze in western U.S.
  - Largely free of sulfate haze
  - Ozone smog and nitrate-based haze plague much of southern California because of automobile emissions

Visibility and restrictions

- Haze forecasting
  - Occurs a day or so (48 hours) after a cP air mass has settled over the area and surface winds are light (<8 knots)
  - Subsidence inversion at 850 to 900 mb
  - Haze movement may be estimated by trajectories at the 850-mb level in the eastern U.S.

Visibility and restrictions

- Haze will dissipate and visibilities will increase with the arrival of mT air from the western Atlantic in the form of a “tropical surge”
  - Main axis of the Bermuda High rotates clockwise from its usual east/west orientation along 30 or 35° N latitude
  - This is in response to the development of a strong trough over the Mississippi Valley
  - It could also be in response to the development of a closed circulation along the south Atlantic Coast
  - Both scenarios result in deep S-SW flow over the mid-Atlantic States and New England

Visibility and restrictions

- Haze may form when cool air moves over warmer water with wind speeds of 10 to 20 knots and may produce a shallow inversion (50 to 100 feet), capping sea salts

Visibility and restrictions

- Smoke is a local problem of short duration
  - Due to bombing/artillery fire, industry, forest fires etc., in a stable atmosphere
  - Dissipate - eliminate source and/or destabilize atmosphere by strong wind, turbulent mixing
  - Marine environment - similar to haze situations

Visibility and restrictions

- High winds and very dry soil cause blowing dust/sand
  - Desert regions - areas of disturbed surface (military OPs, construction) most likely sources
  - Droughts, in conjunction with haphazard irrigation practices
  - Wind >15 knots required raising and advecting significant amounts of fine dust (Saudi Arabia, Iraq/Iran, Sahara desert)
  - Wind >25 kts required to raise and advect sand/soil

Visibility and restrictions

- Most severe cases of blowing dust/sand associated with thunderstorm outflow boundaries (called "Haboobs" in Mid-East)
- High wind behind a cold front may advect soil/sand hundreds of miles (horizontal) and thousands of feet aloft
- Once lifted, fine dust may remain suspended for days after winds subside
- Higher RH of marine regions will reduce visibilities more than drier air

Visibility and restrictions

- Blowing Snow
  - Snow cover which has previously been subject to wind movement (blowing or drifting) will not give as severe a visibility restriction as that caused by snow that has not previously been blown
  - Snow that falls with temps near freezing will not blow easily (wind ≥25 knots is needed)
  - Snow packs that have been undisturbed for a long time will not be blown

Visibility and restrictions

- Loose (drifting) snow becomes blowing snow with 10-15 knots or greater
- Fresh snow will be loose at temperature ≤-4˚F
- Snow that has been exposed to sunlight (clear or scattered skies) for three or more day's crust, so it won't blow

Visibility and restrictions

- Pollutants
  - Air pollution is essentially produced by sources emitting gases, aerosols or particles within a space that is unable to dilute or disperse the pollutants
  - Air pollution dissipation is quite similar to haze dispersal

Local Area Work charts

- Purpose
  - Used to identify specific meteorological elements that require special analysis
  - Used to supplement and sometimes replace centralized products and is available from AWDS, MIDDS, and the Internet
  - Examples - ceilings, precipitation areas, mesoscale systems, etc.
- Scale is mesoscale and is used for systems that vary from 1-500 nm in the horizontal dimension

Local Area Work charts

- Continuity
  - Review continuity from previous analysis
  - When available, 3, 6, and 12 hour limited positions, pressure systems and squall lines
  - Clearly label by time
  - Construction of trends and time linear charts may be necessary to maintain accurate, meaningful continuity

Local Area Work charts

- Basic Analysis Concepts
  - Draw for data
  - Compare to satellite photos
  - Be careful about throwing out data that does not seem to fit the pattern

IR

Local Area Work charts

- Isobaric Analysis rules
  - Analyze every 2-mb starting at 1000 mb
  - If required, or to determine the features on the charts, analysis of every 1/2-1mb can be accomplished. if so use dashed lines
  - Identify and label all pressure centers, troughs, squall lines etc.
  - Final Analysis refinement

Local Area Work charts

- Finalized chart
  - Harden in all isobars fronts troughs, squall lines etc.
  - Harden pressure centers to include center symbol and central value
  - Present Weather
    - Color and shade all present weather IAW HO-301
    - Outline areas of precipitation by type

Local Area Work charts

- Nephanalysis (cloud)
  - CIGS <1,000' will be enclosed with a solid red line and shaded red
  - CIGS 1,000-2,900' (inclusive) will be enclosed with a scalloped blue line and the area shaded blue
  - CIGS 3,000-9,500' (inclusive) will be enclosed with a scalloped purple line and the area shaded purple
  - CIGS ≥10,000' will be enclosed with a scalloped brown line and the area shaded brown

- APPLICATION: Students will complete forecast worksheets utilizing data/charts from WTSE
- EVALUATION: Students will complete a forecast worksheet using data/chart set WTSE.